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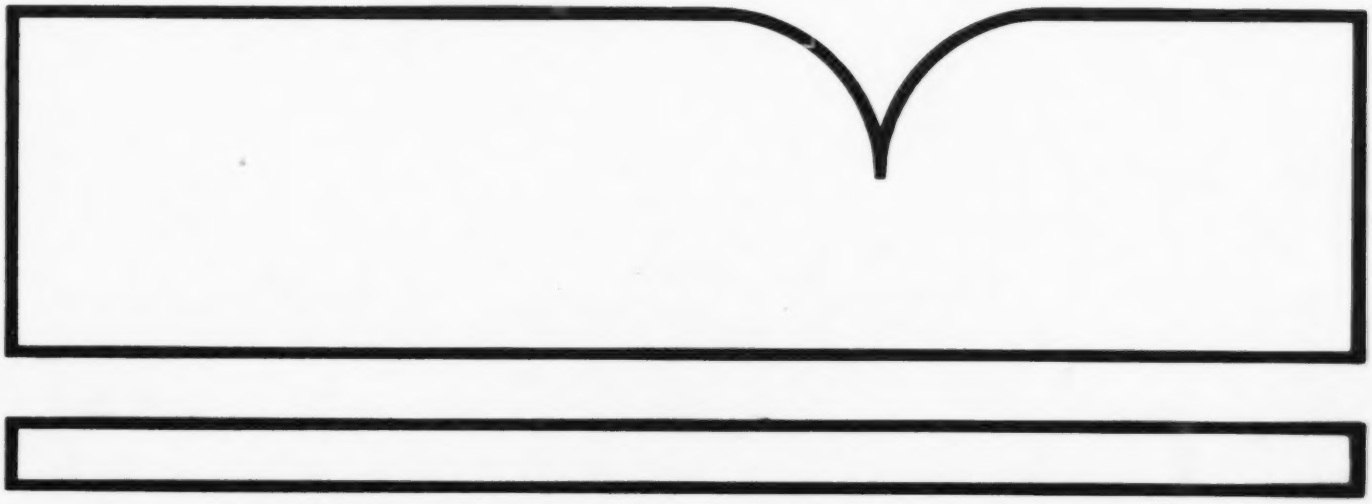
Compare Nitrate Removal Methods For Some Communities, Ion Exchange May Be the Most Economical, Practical Way of Handling Nitrate-Contaminated Groundwater

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

Dec 80



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16. ABSTRACT

Nitrate is a ground water contaminant that results from fertilizers and septic tanks wastes. Many treatment methods have been investigated for nitrate removal but only ion exchange, reverse osmosis and electrodialysis are considered to be practical. Of these three methods, ion exchange is the most economical and thereby will be the method selected by most communities. The most important aspect of ion exchange treatment is the level of sulfate in the source water because ion exchange resins are more selective for sulfate removal than nitrate removal. Cost comparison of nitrate removal methods are presented and compared with other treatment techniques such as lime softening, ion exchange softening, and activated alumina treatment for fluoride removal.

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Compare nitrate removal methods

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Journal Article

For some communities, ion exchange may be the most economical, practical way of handling nitrate-contaminated groundwater

By Thomas J. Sorg

ION EXCHANGE TREATMENT is often less costly than reverse osmosis or electrodialysis and may be more acceptable than the alternatives to treatment.

The two principal sources of nitrate contamination of water sources are fertilizers and septic tank wastes. Thus, the most vulnerable water supplies are groundwaters in agricultural areas and in areas with a large number of septic tanks.

Solutions to the nitrate contamination problem in groundwater are numerous. Treatment is just one of the potential remedies. Good engineering practice requires that all alternatives to treatment be explored for their feasibility and cost effectiveness as compared to treatment. Most small communities have limited resources, so treatment will very likely be selected as a last resort.

Three alternatives to treatment are development of another water supply, blending of two or more water supplies, and connecting to approved water supply. Each has advantages and disadvantages depending on the conditions and circumstances in each community, (Table 1).

1—ALTERNATIVES TO TREATMENT

Alternative	Advantages	Disadvantages
Development of new water supply	Less expensive Short time implementation	Modifications to distribution system Water quality may change
Blending two or more water supplies	Less expensive Short time implementation	Extensive modifications may be required
Connect to approved water supply	Less expensive Short time implementation, Few modifications	No control over water supply Dependent on another utility

2—TREATMENT METHODS

Method	Effectiveness
Chemical coagulation	Not effective
Lime softening	Not effective
Chemical reduction	Has potential, but not practical
Biological denitrification	Has potential, but not accepted
Ion exchange	Effective
Reverse osmosis	Effective, but costly
Electrodialysis	Effective, but costly

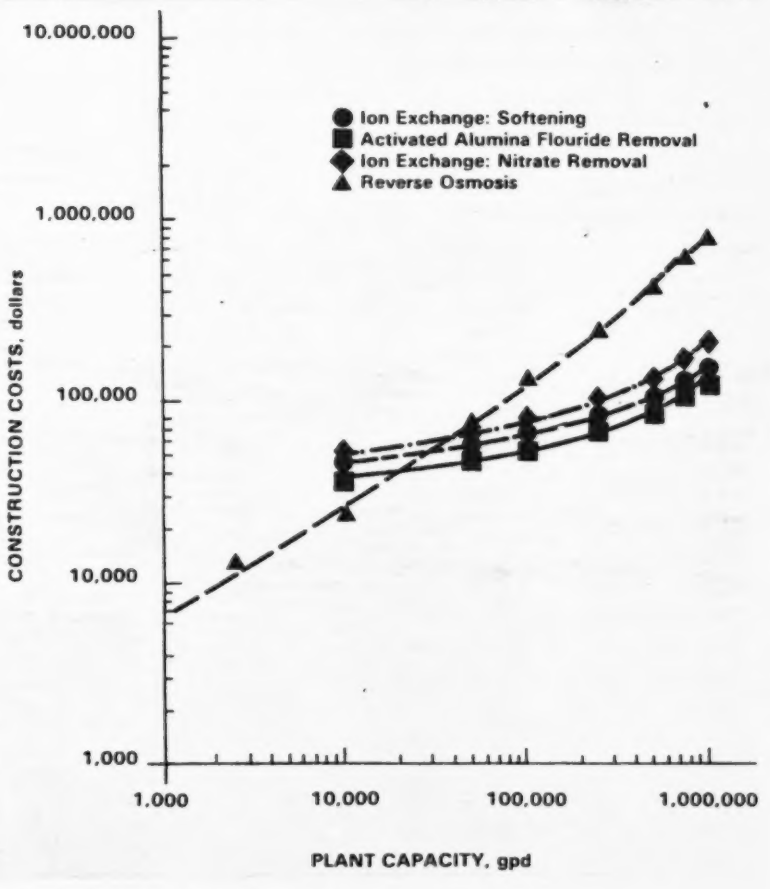

Fig. 1: Treatment process construction costs

Sorg is the chief of the Inorganic & Particulate Control Section in the EPA Office of Research and Development

(*Continued from page 26*)

Obviously, the most simple approach is the development of a new water supply, such as drilling a new well. This assumes a nitrate-free water source exists in the area. With advanced drilling techniques, water can be drawn from specific strata, or the contaminated source can be sealed off. The major disadvantage is that the water quality might change with pumping and time.

Another approach is to blend water from different sources to achieve a nitrate concentration in the blended water below the maximum contaminant level (MCL) of 10 mg/l (as N). This solution assumes that a good source of water exists for blending with the high nitrate water. Modifications to the distribution system will be required to provide mixing — modifications that could be very expensive.

A third solution is to obtain water from a neighboring community. The community then gives up control over its drinking water and becomes dependent on another community or utility. Some communities may not be willing to relinquish this control and would be willing to pay the higher cost of developing a new supply or providing treatment.

Although each alternative seems to be a straightforward, simple approach to the problem, each solution has certain disadvantages from either an economic, engineering, or political viewpoint. In the final analysis, each solution may be either more expensive than treatment or unacceptable.

Several treatment techniques have been studied for the removal of nitrate from drinking water: chemical reduction,[1,2,3] biological denitrification;[4,5] ion exchange;[6,7,8] and reverse osmosis;[9,10] (Table 2).

Of these methods only the latter two, ion exchange and reverse osmosis, are considered feasible and practical for full-scale treatment of drinking water. Electrodialysis is very similar to reverse osmosis and is also effective for nitrate removal.[11] Neither conventional coagulation nor lime softening are effective removal methods because nitrate is very soluble in water.

Several chemicals have been investigated for reducing nitrate to nitrogen gas. Only ferrous iron has been determined economically attractive. The process requires a catalyst, copper, for denitrification and must take place in an alkaline solution. Other drawbacks are that only about 70% of the nitrate is reduced, and large amounts of ferrous iron are required, (eight moles of iron per mole of nitrate).

Biological method not accepted

Biological denitrification has been studied for the purification of wastewater and drinking water. The process requires the use of denitrifying organisms in a filter bed to reduce the nitrate to nitrogen gas. It also requires an organic energy source for the bacteria, such as methanol or ethanol, be added to the water because most groundwaters are low in organic content.

In general, the water utility industry has not accepted this process because an organic material has to be added to water that is generally free of organics; the process requires careful control; a large bacterial population has to be developed in water that is generally free of organisms; and the system will be out of service if the biological mass is lost.

As long as other alternatives exist for nitrate removal, this process will probably be given very little serious consideration for drinking water treatment, particularly in small communities.

Currently, ion exchange treatment is the only treatment method used on a full scale level to remove nitrate from drinking water. In 1974, a full scale plant was constructed by the Garden City Park Water District, Nassau County, N.Y., to treat ground water containing 20–30 mg/l of nitrate-nitrogen.[6] The plant was designed to treat 0.08 m^3/S (1200 gpm) and to lower the nitrate-nitrogen level to less than 2 mg/l.

The Garden City Park facility employs

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a continuously regenerated ion-exchange process in a closed loop. This process is used in industrial applications but uncommon in drinking water treatment. Its major advantage is that the resin material is continuously regenerated; large slugs of brine solution for disposal are avoided. Greater efficiency of the media for nitrate capacity is also projected.

As of Sept. 1979, the system was operating successfully, but not on a full time basis. Because most small communities cannot afford such an elaborate system, the more common fixed bed system would have greater application. The Garden City Park system, however, has demonstrated that ion exchange technology will work for nitrate removal.

The economics, removal efficiency, chemical usage, and so forth will vary with the quality of water, and the operation of the Garden City Park plant cannot be universally projected to other locations. For example, the most significant factor of the water is the sulfate concentration because up to a total dissolved solid (TDS) concentration of about 3000 mg/l, sulfate is preferred over nitrate. High sulfate water is more costly to treat than low sulfate water because the sulfate competes with nitrate and thus lowers the nitrate removal efficiency. The Garden City Park ground water is low in sulfate (30–40 mg/l) and its ion exchange system is relatively efficient for nitrate removal.

High sulfate water tested

To evaluate the influence of higher sulfate water, the Drinking Water Research Division of the EPA funded a research project in McFarland, Ca., that has a ground water containing near 20 mg/l of nitrate-nitrogen and about 300 mg/l of sulfate. The project is investigating the effectiveness and efficiency of ion exchange and reverse osmosis treatment. The project was about half completed as of Jan. 1980 and is scheduled for completion by Dec. 1980.

Two other treatment methods, reverse osmosis and electrodialysis, will remove nitrate, but these methods are used primarily for treating high TDS and salt water. The nitrate removal efficiency by reverse osmosis varies with the type of membrane; a wide rejection range of 60–95% is reported.[9,10] Neither method would probably be selected solely for nitrate removal because of the high cost. If the water has several other contaminants or is high in TDS, the techniques may be practical and economical.

Ion exchange, reverse osmosis, and electrodialysis equipment are readily available from a variety of equipment manufacturers. Because the efficiency of ion exchange treatment for nitrate

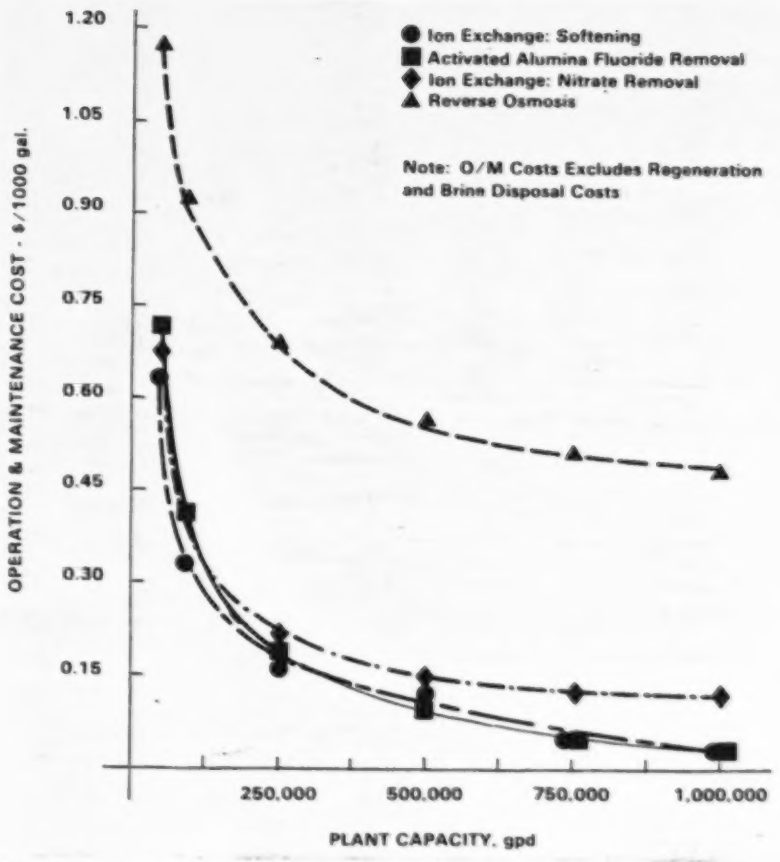

Fig. 2: Operating cost data for various processes

3—CONSTRUCTION COSTS—WATER TREATMENT SYSTEMS[12]

Plant Capacity gpd	Construction Costs, $ Ion Exchange Softening	Activated Alumina Fluoride Removal	Ion Exchange Nitrate Removal	Reverse Osmosis
50,000	60,500	50,000	65,000	78,000
100,000	68,000	58,000	74,000	131,000
250,000	85,000	72,000	98,000	245,000
500,000	106,000	92,000	129,000	430,000
750,000	131,000	110,000	170,000	625,000
1,000,000	150,000	130,000	221,000	778,000

4—CONSTRUCTION COST BREAKDOWN[12]

Cost Category	Construction Cost, $ Ion Exchange Softening 280,000 gpd	Ion Exchange Nitrate Removal 270,000 gpd
Site work	640	110
Manufactured Equipment		
Equipment	16,000	16,500
Media	6,780	21,880
Concrete	1,400	490
Steel	2,170	680
Labor	7,430	5,990
Pipe and valves	12,600	12,440
Electrical & instrumentation	21,800	21,480
Housing	8,900	8,900
Subtotal	77,270	88,430
Miscellaneous & Contingency	11,590	13,260
Total	88,860	101,690

5—OPERATION AND MAINTENANCE COST[12]

Yearly O&M Cost, $ and (¢/1000 gal)

Plant Capacity (gpd)	Ion Exchange Softening	Activated Alumina Fluoride Removal	Ion Exchange Nitrate Removal	Reverse Osmosis
50,000	11,500	13,000	12,400	21,300
	(63)	(71)	(68)	(117)
100,000	12,200	15,000	15,000	33,500
	(33)	(41)	(41)	(92)
250,000	15,500	18,000	20,000	63'000
	(17)	(18)	(22)	(69)
500,000	19,800	18,000	26,900	104,000
	(11)	(10)	(15)	(57)
750,000	23,000	20,800	34,800	142,000
	(8)	(8)	(13)	(52)
1,000,000	25,300	23,700	46,000	180,000
	(7)	(6)	(13)	(49)

Costs include maintenance material, energy, and labor and exclude regeneration and brine disposal

removal is dependent on the water quality, pilot-plant studies on the specific water are recommended for developing design and operational data. Once this data is established, most water treatment equipment manufacturers can easily specify the size of anion exchange beds and other ancillary equipment.

Reverse osmosis and electrodialysis equipment is also available from a large number of manufacturers. Pilot studies are not necessary as long as the water quality is known.

Of the three most effective and practical methods, (ion exchange, reverse osmosis, and electrodialysis), ion exchange is the most economical for low TDS water. The equipment for ion exchange nitrate removal is similar to ion exchange softening equipment and activated alumina fluoride removal equipment, so the construction costs for all three processes should be comparable.

Treatment costs compared

A recent EPA publication on the costs of water treatment process, developed by Culp, Wesner, Culp, confirms this, (Table 3, Fig. 1).[12] In ascending order of total construction costs up to about 1 mgd, four comparable processes are activated alumina for fluoride removal; ion exchange softening; ion exchange nitrate removal; and reverse osmosis. The costs for the first three processes differ by only a small amount. Reverse osmosis costs about 2–3 times more than the other methods.

The principal difference in the construction costs for ion exchange softening and nitrate removal is the media expense. Table 4 provides a breakdown in the construction costs of 1136 m^3/d (0.3 mgd) plant. All of the cost categories shown are approximately equal except for one, the ion exchange media. The anion resin for nitrate removal costs about three times more than the cation resin used in the softening process.

Operating cost data for the various processes are compared in Table 5 and Fig. 2. This data includes total costs for maintenance materials, energy and labor and excludes the cost of regeneration and brine disposal. The operation costs for ion exchange nitrate removal are about 5–30% higher than ion exchange softening costs. Reverse osmosis treatment is 2–5 times more costly than ion exchange.

Regeneration and brine disposal expenses increase costs and depend on the efficiency of each process. For ion exchange, regeneration costs are a function of the quality of the water and, in particular, the total amount of sulfate, nitrate, and other anions in the water. Because sulfate is preferred over nitrate, the regeneration costs for nitrate ion exchange are primarily dependent

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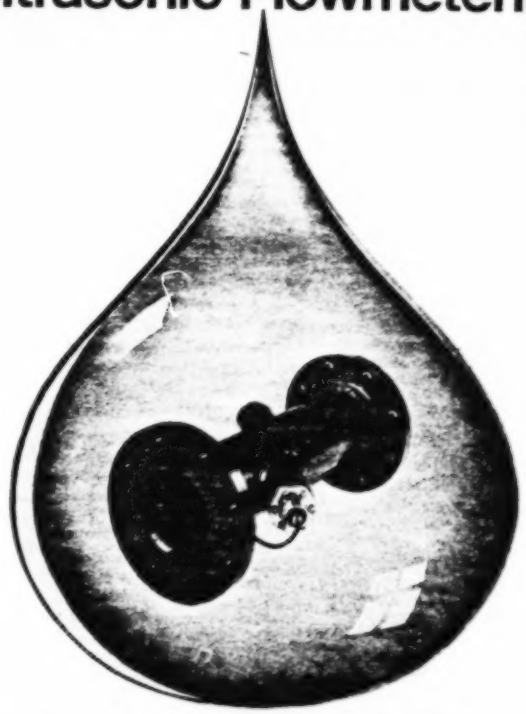

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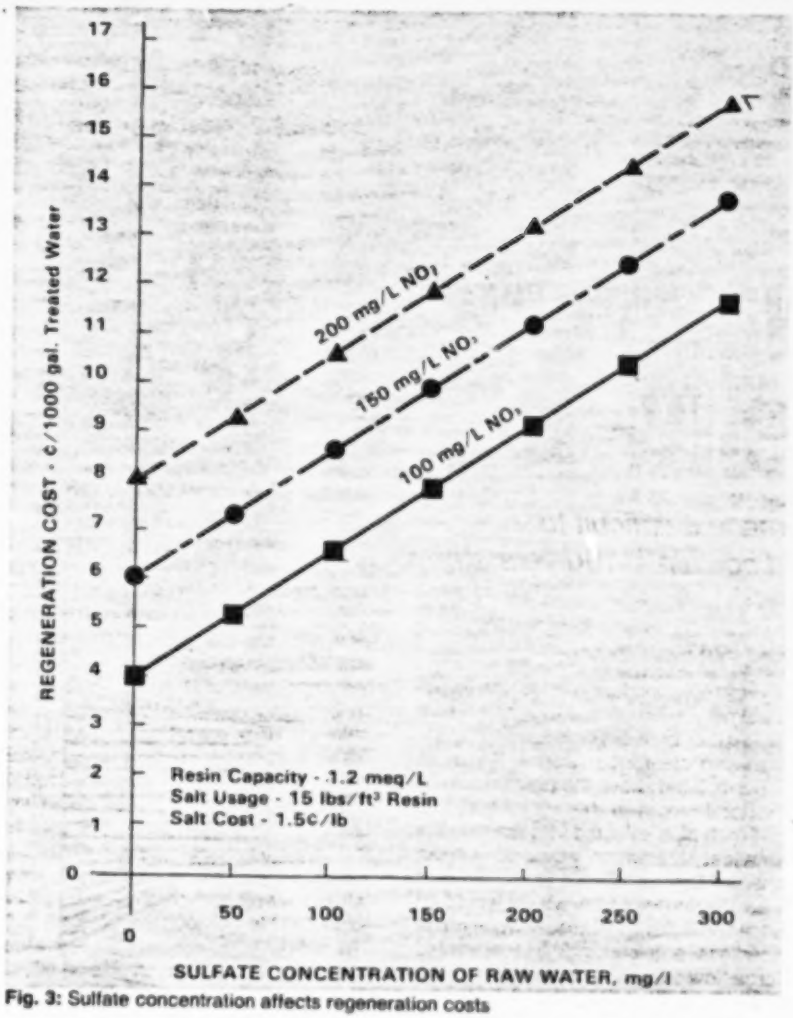

Fig. 3: Sulfate concentration affects regeneration costs

on the amount of sulfate in the raw water.

To evaluate the effect of sulfate on the regeneration costs for ion exchange nitrate removal, cost data was developed that assumes 100% efficiency in removal of sulfate and nitrate; a capacity of 1.2 meq/ml of resin; 240 kg of salt per cubic meter of resin (15 lbs/cu. ft.) for regeneration; and 1.5¢/lb of salt.

This data, (Fig. 3), shows the sulfate concentration can increase regeneration cost substantially. The costs will double as the sulfate concentration increases from 50 to 250 mg/l. Increases in salt usage and salt prices will also increase these costs. Figure 3 also shows that regeneration costs are a major portion of the operating costs than can amount to 40–50% of the total costs. By including regeneration costs in the total operating costs for ion exchange treatment the gap is narrowed between this treatment method and reverse osmosis. □□

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Dredging will help save lake

A major effort is underway to save an artificial lake in Albuquerque, N.M. from the ravages of neglect. Lake Tingley was once a pleasant place to escape from the arid desert summer. Recently, however, the lake has been an eyesore—clogged by debris thrown there by litterers.

An integral part of the renovation effort is the use of a portable hydraulic dredging system. This system was chosen because of the lake's fragile white clay bottom which might have been damaged by the use of more conventional methods for removing sediment.

The clean up effort will require more than 500 hours of dredging before the lake will again be able to support fish and other wildlife.

But according to site supervisor Barry Ward, nearby residents are already benefiting from the dredging.

"The people who live near here," he said, "can already smell the difference."

"You can't imagine what kinds of things we're finding at the disposal site," he continued. ". . . everything from beer cans and sun tan lotion bottles to rocks and old shoes."

The dredging equipment known as the Mud Cat is manufactured by National Rent a Car Systems. According to a company official, this is the first time such equipment has been used in the Southwest.

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